FINAL TECHNICAL REPORT

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(Entitled "Biologically Produced Volatile Compounds: Studies of N_2O Fluxes at the Soil-Atmosphere Interface in Various Ecosystems and Their Impact on the Global N_2O Budget")

ANNUAL CYCLES OF N_2O PRODUCTION AND TRANSFER AT THE SOIL-ATMOSPHERE INTERFACE IN A DESERT SITE

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ABSTRACT

N_2O concentrations in a desert soil profile were measured weekly to biweekly over 2 annual cycles in Gilgal, Jordan Valley, Israel. The average concentration for the whole period varied between 0.366 ppm ($\pm$0.086) at the top 2 cm and 0.386 ($\pm$0.115) at 30 cm depth. Increases in N_2O concentration were observed at all depths during the late winter-spring period and resulted in net flux of N_2O from the soil to the atmosphere. Increased N_2O production in desert soils is attributed to nitrification of NH_4 released during decomposition and ammonification of organic residues. If representative of desert ecosystems on the global scale, this seasonal burst in N_2O emission may contribute to the increased atmospheric N_2O concentration in the northern hemisphere observed in the spring.

INTRODUCTION

Desert soils constitute some 36% of the land areas of the Earth (1). Their role and participation in the global biogeochemical cycles has not been studied thoroughly. We report here the results of detailed observations of the annual cycle of N_2O production in a desert site in the Jordan Valley, Israel. Observations of a short period of slightly increased N_2O production in the soil and emission to the atmosphere in the spring were recorded. A few possible events of N_2O uptake/destruction in this desert soil were also measured.

EXPERIMENTAL

Measurements were conducted at a desert site in the Jordan Valley, Israel (32°N, 35°27'E, - 270 m elevation). The area receives an average of 140 mm annual precipitation, concentrated in the winter months. The mean annual temperature is 23.1°C with a mean monthly minimum in December of 8.9°C and mean monthly maximum in July of 38.2°C. The soil is a fine sandy clay loam containing 55% sand, 20% silt and 25% clay, 1.33 organic matter and

39.6% carbonate as calcite. The pH of the saturated soil paste was 7.4, the electrical conductivity of the saturated paste extract was 2.7 ds/m, and the content of NO_3^- in the soil extract was 0.32 meq/L. The soil is not and has not been cultivated according to local records.

Five replicate soil air samplers were installed at each depth of 2 cm, 6 cm, 15 cm and 30 cm. Soil-air was sampled weekly to biweekly by slowly drawing with a syringe, 15 ml of air from the permanently installed samplers. The sampled air was injected into 10 ml pre-evacuated glass test tubes ("Vacutainer") capped with rubber septa, and analyzed in the laboratory for N_2O using Tracor 540 gas-chromatograph equipped with a Tracor electron capture linearizer which operated a Tracor ^{63}Ni ECD in the constant current pulsed mode, following the method of Mosier and Mack (10).

N_2O flux at the air atmosphere interface was measured by the "chamber method". A transparent poly-carbonate box was temporarily placed on and sealed to a 20x40 cm steel frame permanently installed in the soil. Samples of 18 ml air were slowly drawn by a syringe equipped with a 10 cm long needle through a rubber septum in the box, intermittently over a period of 90-120 min. The temperature in the chamber air was recorded during the period of sampling, and temperature corrections to the sampled volume were entered. N_2O flux from/into the soil was calculated from the changes in N_2O concentration in the chamber. The measurements were done in duplicate chambers. Atmospheric air samples were taken in triplicate from heights of 10, 30, 80, 250, 350 cm above ground level using a meteorological mast.

During the study period, soil temperature was recorded (Fig 1.). The rainfall distribution during the study period is given in Fig. 2.

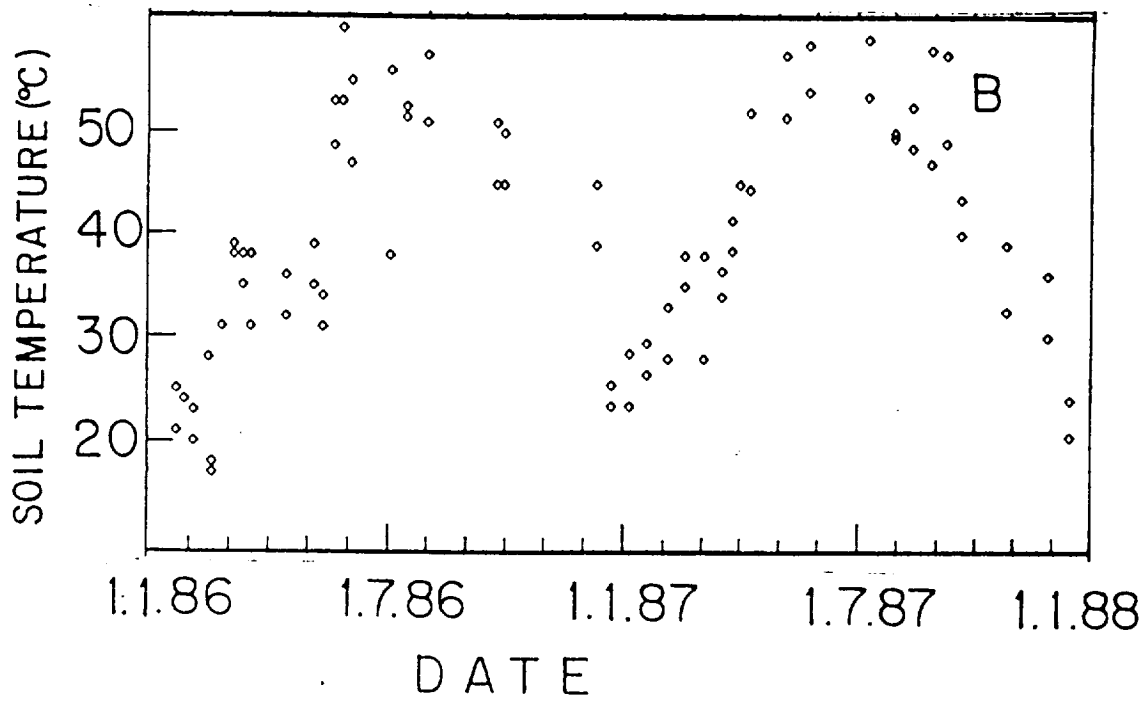

Fig. 1. Soil temperature at 2 cm depth in the area which was closed by the gas-flux measuring chamber.

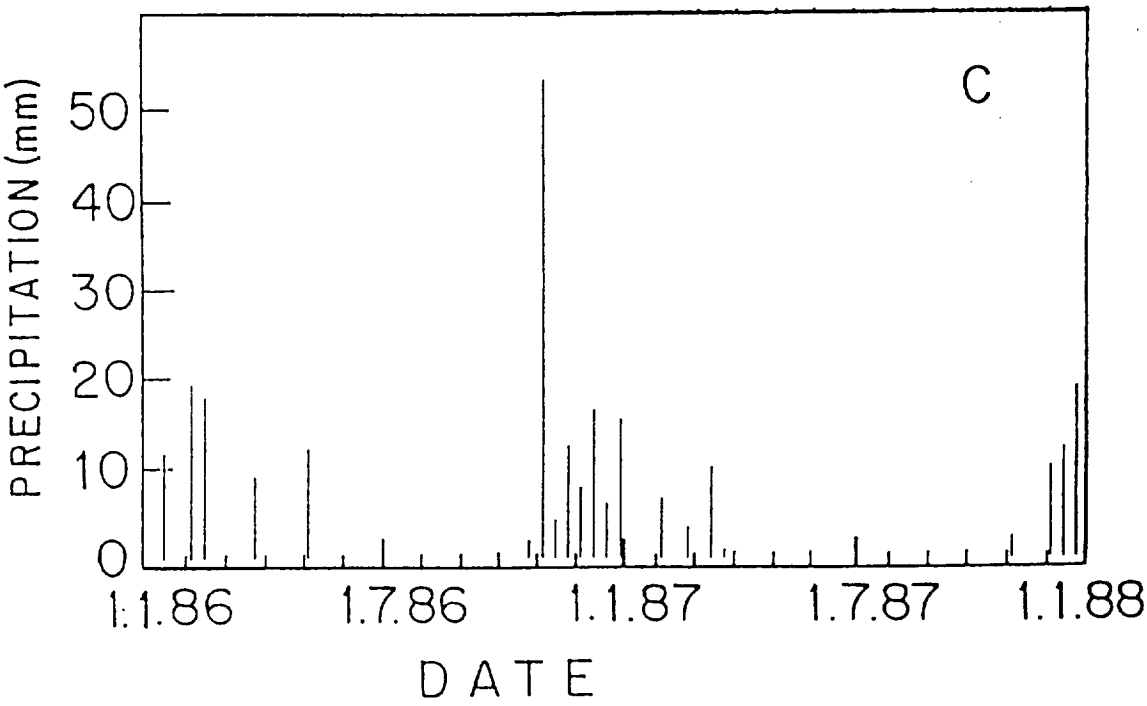

Fig. 2. Atmospheric precipitation (cumulative for ten day intervals) in the experiment site.

RESULTS AND DISCUSSION

Figure 3 shows the variation of N_2O concentration in the soil profile, and Figure 4 shows the N_2O fluxes measured from the soil. The concentration of N_2O in the soil is usually low, only slightly higher than that of the ambient atmosphere. It tends to increase with depth and shows seasonal variation. Of particular interest is the seasonal increase in concentration in the spring - observed during February-March 1986 and March-April 1987, causing increased flux from soil to atmosphere. We attribute this phenomenon to N_2O formation by biological nitrogen transformations.

N_2O is produced both during denitrification and nitrification. Generally, the production rate is higher during denitrification. However, in desert soils nitrate is known to accumulate in the upper layers of the soil by the sequence of processes involving organic matter decomposition, ammonification and nitrification (2). The decaying plant organic matter (roots) in the soil profile releases NH_4^+ which is then nitrified by nitrifying bacteria with concomitant release of N_2O. In some cases, denitrification was observed as leading to N loss through N_2 and N_2O emissions from desert soils (3). However, this process seems unlikely under the conditions of a warm and dry top-soil studied in our experimental site.

In the precipitation regime which prevails in the Jordan Valley, the soil is wetted at the upper layer only for a short period, usually in the months of December-February each year. During this period, annual weeds sprout, develop, cover the soil and finish their short growth cycle. Then the soil is quickly dried due to the warm weather conditions, and aerobic conditions prevail. The emissions which we observed (Fig. 4) occur at the end of the winter and the early spring. At this stage, the soil is dry and denitrification as N_2O source is not likely. We suggest therefore that the observed surge in N_2O emissions is due to nitrification.

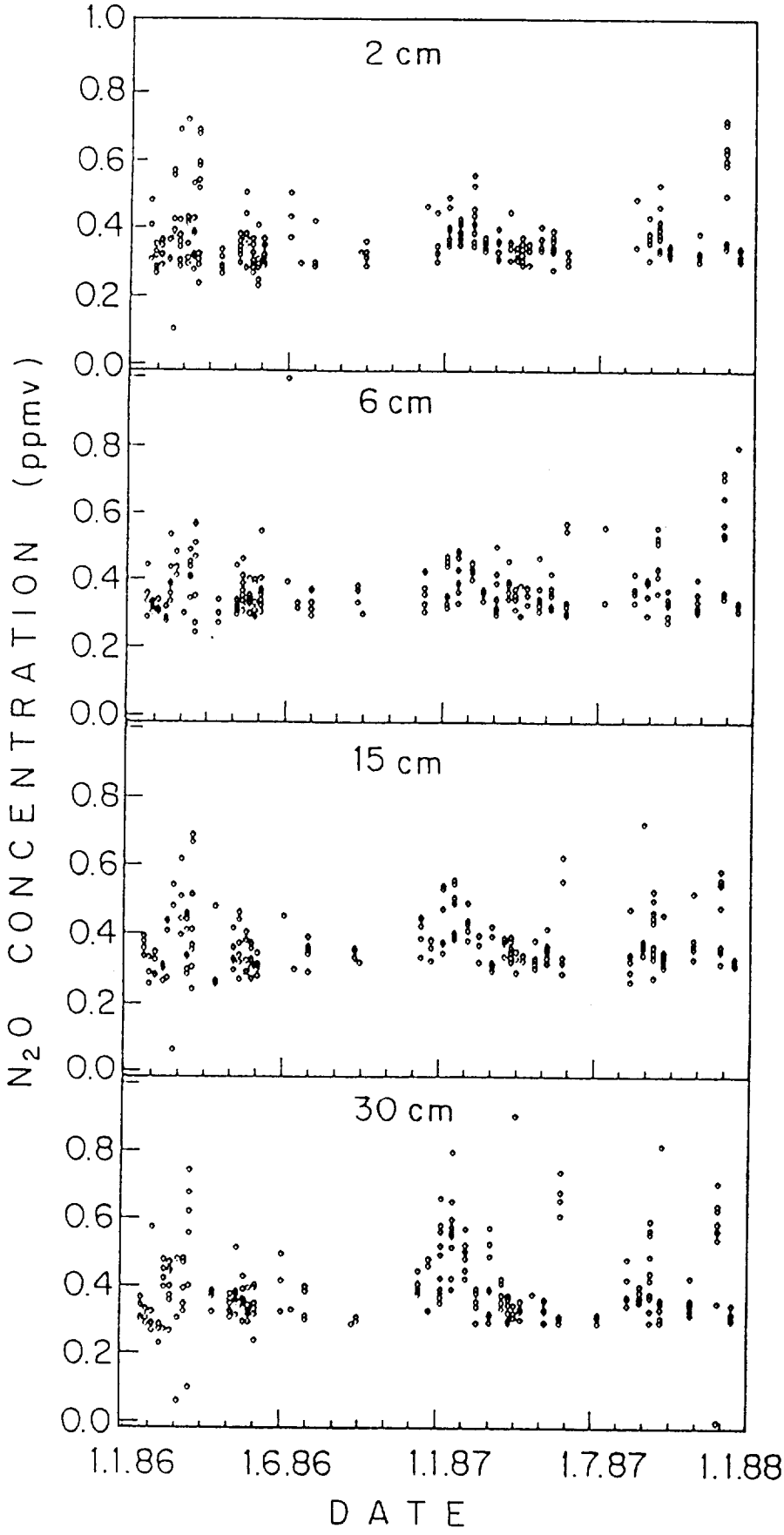

Fig. 3. The variation of N_2O concentration at four depths (2,6,15,30 cm) in a desert-soil profile over a 2 year cycle.

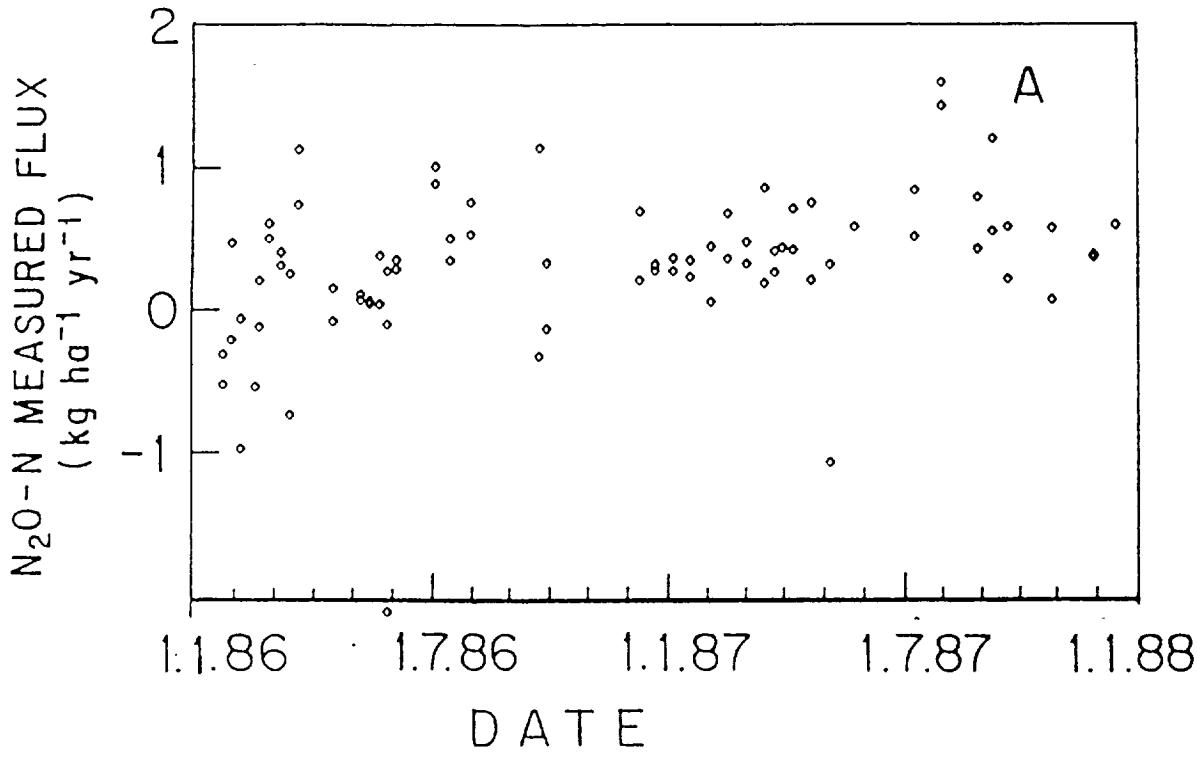

Fig. 4. N_2O flux from a desert-soil (Gilgal, Jordan Valley, Israel) over a 2 year period.

This seasonal burst of N_2O coincides in time with the N_2O burst observed in cold region soils (tundras) during thawing (4) and in more moderate humid climates during the early spring (5). The mechanisms responsible for these natural soil processes taking place in the hot deserts and the cold and humid regions appear to differ, however. In the cold-humid regions, emission from soils has been suggested to be due to bacterial denitrification in the water-saturated soils during spring warming. At that time, anaerobic conditions may develop in the soil prior to the growth of the seasonal plants and the drying of the soil. In the desert, we propose the N_2O emissions from soils are mainly due to nitrification. On the global scale, these seasonal N_2O emission bursts from both cold and desert soils coincide in time and may explain the seasonal

seasonal increase in atmospheric N_2O concentration over the northern hemisphere during the spring season (6).

Several events of "negative" flux were also measured (Fig. 4), indicating, perhaps, uptake of N_2O into the soil by biological consumption or destruction of the gas by thermal or photochemical mechanisms. These were recorded mostly during 1986, particularly in the early winter. During some of these events, the N_2O concentration gradient in the soil was negative, i.e. deeper soil horizons had lower N_2O concentration than atmospheric. However, in most cases, it appeared that the N_2O "uptake" was limited to the top thin layer of the soil. This may support the possibility of catalytic decomposition reactions of N_2O adsorbed on desert soil particles (7). If corroborated by additional measurements, it may account for some of the puzzling discrepancies in the global N_2O budget (8,9) by providing an additional global sink for N_2O.

CONCLUSION

The present measurements are, to the best of our knowledge, the first to accurately document N_2O dynamics in desert soils. They show that even though N_2O production in the arid regions may not be high compared to more productive ecosystems, due to their large global aerial extent, their effect on the global cycles of N_2O may be of significance, at least in affecting the seasonal cycles of atmospheric N_2O and possibly by acting as an additional global sink for this important trace gas.

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